Letters to the Editor.

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The Separation of the Element Chlorine into Normal Chlorine and Meta-Chlorine, and the Positive Electron.

THE very important letter of Dr. Aston in NATURE of December 18, 1919, gives much evidence in favour of a theory of the structure and composition of the nuclei of complex atoms as published by me five years ago and in a number of more recent papers. This theory led me to the idea, as published at that time (Journal of the American Chemical Society, xxxvii., pp. 1367–96, especially pp. 1390, 1391, and 1387), that among the light elements magnesium, silicon, and chlorine, in addition to neon (as found by Thomson), are mixtures of isotopes. The atomic weights of the normal isotopes were given as 24 for magnesium, 28 for silicon, and 35 for chlorine. It was also stated that nickel, copper, zinc, and practically all the other elements between atomic numbers 28 and 80, the latter being mercury, are mixtures of isotopes; while radio-active evidence shows that elements 81 (thallium) to 92 (uranium) exist in isotopic forms. This theory was recently summarised in a paper sent to the *Physical Review* in May and November, 1919. This paper, as well as the others, should be consulted for the details of the theory.

In February, 1916, I announced that we were working in this laboratory upon the separation of chlorine into isotopes by diffusion (*ibid.*, xxxviii., p. 221, 1916). Early in 1917 Mr. W. D. Turner, my research assistant, found slight differences in density between the heavy and light fractions obtained by diffusing chlorine, but, since small amounts of impurities were very difficult to exclude, this did not seem at all conclusive. Since if there are two isotopes of chlorine there are three molecular forms of the substance, a separation may be made more easily by the use of hydrogen chloride gas, and this has been used in nearly all our work for the last three years, though practically nothing was done during the period of the war.

The diffusion of this gas, as carried out on a moderately large scale by Mr. C. E. Broeker and myself, seems now, judging by our preliminary analyses, to be resulting in a definite separation of the gas into a heavier and a lighter fraction. The separation, while extremely slow, seems from our preliminary results on the heavy fraction to be of about the order to be expected by the Rayleigh diffusion theory, provided the atomic weights of the isotopes are 35 and 37; so the work is in good agreement with that of Dr. Aston. These results may be modified somewhat when our precise atomic weight determinations are made, since at the present time all our determinations are made by rapid methods. Our results suggest, but are not of a sufficient precision really to indicate, the possibility that a third isotope of higher atomic weight may exist, but since the separation is extremely slow, and the positive ray method as worked out by Dr. Aston gives results very quickly, he should be able to test this suggestion much more rapidly than ourselves.

Since 1916 we have diffused about 19,000 litres of hydrogen chloride gas as measured under standard conditions. The apparatus now in use will diffuse about 400 litres per day, and we hope soon to raise the capacity to 1000 litres. These numbers refer to the fresh or ordinary gas introduced into the apparatus, and not to that which is rediffused in smaller units. The total number of units now in operation is five, and the method may be described as a fractional diffusion.

While the idea that the hydrogen nucleus may be the positive electron is a very general one, the only evidence I have found in print which gives real support to this idea, and explains the facts which seem opposed to the idea, is to be found in papers by my associates and myself as cited above, and in my other papers listed at the end of this letter. The hydrogen nucleus or the positive electron has, according to these papers, a weight, and presumably a mass, of 1·000, on the basis of oxygen as 16·000, whenever the positive electron is combined in a complex atom. The atomic weight of ordinary hydrogen is 1·0077. The difference between 1·0077 and 1·000 is due either to the existence of meta-hydrogen of atomic weight 3·00 and composition $(\eta_3\beta_2)+e^-$ in ordinary hydrogen, or else to an electromagnetic packing (possibly to both), the latter as assumed by Sir Ernest Rutherford and by myself, but the details of which are to be found in my papers. In these formulæ $\eta+$ is the positive electron, $\beta-$ the negative electron when it is contained in the nucleus, and e^- when it is a non-nuclear or planetary electron.

The nuclei of atoms are built almost entirely from the following particles[1]:—

		Weight (oxygen basis)
Alpha particle or helium nucleus	$(\alpha^{++})=(\eta^+_4\beta^-_2)^{++}$	4·00
Nu particle or meta-hydrogen nucleus	$(\nu^+)=(\eta^+_3\beta^-_2)^+$	3·00
Mu particle	$(\mu)=(\eta^+_2\beta^-_2)$	2·00

Of these the α particle forms the greater part of all complex atoms; one ν particle is found in most atoms of odd atomic number, at least among the light atoms; and the μ particle, which has no net charge, is responsible for the existence of one of the two known classes of isotopes. The other class of isotopes is due to the presence of the group $\eta^+_4\beta^-_4$, which consists of an α particle, together with two cementing electrons. It is these cementing electrons which are shot off in β disintegrations of radio-atoms, and they always escape in pairs—that is, one directly after the other, or one just before and one just after the escape of an α particle. The number of *negative* electrons in the nucleus of an atom is almost always *even,* whether the nuclear charge is odd or even, but the number of *positive* electrons is nearly always *odd* in a nucleus of *odd charge.* However, the nuclei which contain an even number of positive electrons, and are therefore built up either of α particles alone or of α particles and negative electrons, are, on the whole, much more stable than those with an odd number; so the even-numbered elements are much the more abundant, and make up 98·7 per cent. of the meteorites and the greater part of the material of the earth. Furthermore, all the seven most abundant elements in the meteorites have an even atomic number, as is indicated in Fig. 1.

In the exceptional case of nitrogen the group $\eta_2\beta$ is present, and in beryllium the group $\eta\beta$. A *suggested* structure for the α particle is given in Fig. 2, where the large circles represent negative, and the small ones positive, electrons. The ν group probably has a similar structure, but with three positive electrons at the corners of a triangle; while the lithium nucleus

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[1] The negative electrons in these particles may be called *binding* electrons, while those which attach extra α particles are called *cementing* electrons.

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is assumed to consist of one α and one ν group, with a symmetrical arrangement of the seven positive electrons. *Two α particles do not seem to combine, but from three to eight, and also ten, α particles combine without the inclusion of any cementing electrons*; but when more than ten unite, two or a multiple of two negative electrons are used in cementing on *extra* α particles—that is, α particles which do not contribute to the positive charge on the nucleus.

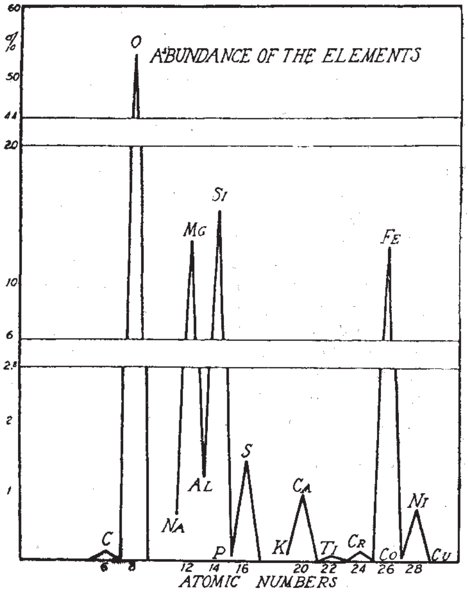

FIG. 1.

Argon and calcium have *isomeric* atoms, the formula of the former being $\alpha_{10}\beta_2 e'_{18}$ and that of the latter $\alpha_{10}e'_{18}e_2$, so both have the general formula $\alpha_{10}e_{20}$. The formulæ given below represent a few characteristic atoms:—

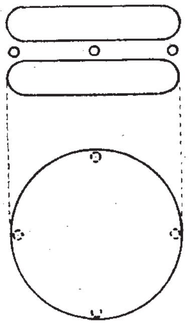

FIG. 2.

Even Nuclear Charge		Odd Nuclear Charge	
C	$\alpha_3 e'_2 e_4$	N	$\alpha_3\eta_2\beta e'_2 e_5$
O	$\alpha_4 e'_2 e_6$	F	$\alpha_4\nu e'_2 e_7$
S	$\alpha_8 e'_{10} e_6$	Cl	$\alpha_8\nu e'_{10}e_7$ and $\alpha_8\nu\mu e'_{10}e_7$
Fe	$\alpha_{14}\beta_2 e'_{18} e_8$	Co	$\alpha_{14}\nu\beta_2 e'_{18} e_9$

Thorium Series		Uranium Series	
Th	$\alpha_{58}\beta_{26}e'_{86}e_4$	U	$\alpha_{59}\mu\beta_{26}e'_{86}e_6$
ThX	$\alpha_{56}\beta_{24}e'_{86}e_2$	Ra	$\alpha_{56}\mu\beta_{24}e'_{86}e_6$
Pb(Th)	$\alpha_{52}\beta_{22}e'_{78}e_4$	Pb(Ra)	$\alpha_{51}\mu\beta_{20}e'_{78}e_4$

Here e represents a valency electron, e' a non-nuclear electron in one of the inner shells, and β a cementing electron in the nucleus. The evidence for these formulæ is good, but cannot be presented here.

It will be seen that this hydrogen-helium-metahydrogen theory of atom-building is based upon the atomic weight and atomic number relations; the Rutherford atom; the rule of Soddy, Fajans, and Russell for radio-active changes; and the atomic weight relations discovered by Rydberg about thirty years ago; and is dependent for its validity upon the existence of chlorine, magnesium, silicon, and the heavy atoms in isotopic forms. It is a resurrection and an extension of the hypothesis of Prout.

References.—J. Am. Chem. Soc., xxxvii., pp. 1367–96 (1915); xxxix., pp. 856–79 (1917); *Phil. Mag.*, xxx., pp. 723–34 (1915); *Science*, N.S., xlvi., pp. 419–27, 443–48 (1917); Proc. Nat. Acad. Sciences, i., p. 276 (1915); ii., pp. 216–24 (1916); *Physical Review*, February, 1920, in press.

WILLIAM D. HARKINS.

Department of Chemistry, University of
Chicago, March 8.

I HAVE read Prof. Harkins's letter with great interest. If Prof. Harkins has succeeded in separating the isotopic hydrochloric acids he is certainly to be congratulated. The very meagre positive results from my work with neon described at the British Association meeting in 1913 convinced me of the extreme difficulty and labour of such diffusion experiments. In the case of neon I had only to grapple with a twentieth root in the diffusion equation, whereas with HCl it is the thirty-sixth root which is involved. In connection with the possibility of a third isotope of chlorine in the full account of my recent analysis of this element, now in the press, I have described a faint line at 39 which may be this.

More experimental results will be required before the time is ripe for the formulation of a comprehensive theory of atomic structure. I do not propose, therefore, to discuss the one put forward by Prof. Harkins, but would like to point out that his basal assumption that the positive electron has a weight 1·000 is definitely contradicted by experimental results quoted in my letter in NATURE of March 4. F. W. ASTON.

Cavendish Laboratory, Cambridge, April 20.

On Atomic and Molecular Structure.

THE statement of Mr. S. C. Bradford in the second paragraph of his letter to NATURE of April 8, that I suppose the electrons to revolve in small circles *without any constraining force*, is erroneous. The fact that I reserved an opinion as to the nature of the constraining force does not imply, as he suggests, that I deny its existence. Thus (*cf. Science Progress*, April, 1920, and Phil. Trans. Roy. Soc., vol. ccxx., p. 247, 1920) an electron moving with speed v perpendicular to a magnetic field of intensity H (which may originate in the nucleus) describes a circular orbit of radius $\rho = mv/H\epsilon$, and the frequency of the electron is $\nu = H\epsilon/2\pi m$, which (and this is an advantage in the case of a radiating orbit) is independent of the speed with which the electron describes the orbit. At present we know little about the actual value of v. If H is of the order 10^7 gauss, the value ascribed to the molecular field from magnetic considerations, the frequency is that of infra-red radiation, and the correlation of the elastic properties of the medium (which are determined by this molecular field) with the infra-red vibrations, as originally pointed out by Debye, is apparent. Within an atom the controlling field may be of the order 10^8 gauss, which gives rise to vibrations of optical frequency. Closer to the nucleus a field of 10^9 gauss gives rise to frequencies comparable with those of a K series.

Finally, it should be pointed out that the ring electron theory, which Mr. Bradford attributes to

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